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14. ABSTRACT

The report covers the first full year of participation of the University of Wyoming (UW) research team in the HI-ARMS project. The principal role of the UW team is the development of an unstructured mesh near body compute engine (NBE) for use within the HI-ARMS software suite. A prototype NBE solver has been developed and tested both for stand-alone test cases, including a hover test case, and in a coupled mode running with the structured grid off-body compute engine (OBE) of the HI-ARMS software. A more thoroughly validated production version of the NBE remains under development. An IBLANK capability has been incorporated into the production version of the NBE, as well as a capability for merging, tracking and

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Report Title

Development of a Near-Body Compute Engine for the HI-ARMS Institute, Final Report for Year 1

ABSTRACT

The report covers the first full year of participation of the University of Wyoming (UW) research team in the HI-ARMS project. The principal role of the UW team is the development of an unstructured mesh near body compute engine (NBE) for use within the HI-ARMS software suite. A prototype NBE solver has been developed and tested both for stand-alone test cases, including a hover test case, and in a coupled mode running with the structured grid off-body compute engine (OBE) of the HI-ARMS software. A more thoroughly validated production version of the NBE remains under development. An IBLANK capability has been incorporated into the production version of the NBE, as well as a capability for merging, tracking and solving multiple blocks of unstructured meshes simultaneously as a single data structure within the solver. At the same time, wrapping of these codes using the Python scripting language has been performed, thus providing a path for software integration in the HI-ARMS project. A mesh deformation solver has also been demonstrated and is currently being packaged for use as a stand-alone code or callable subroutine within the HI-ARMS framework.

List of papers submitted or published that acknowledge ARO support during this reporting period. List the papers, including journal references, in the following categories:

(a) Papers published in peer-reviewed journals (N/A for none)

Number of Papers published in peer-reviewed journals: 0.00

(b) Papers published in non-peer-reviewed journals or in conference proceedings (N/A for none)

A multi-code Python-based infrastructure for overset CFD with adaptive Cartesian grids, A. Wissink, J. Sitaraman, V. Sankaran, D. Mavriplis, T. Pulliam, AIAA paper 2008-0927, presented at the AIAA Aerospace Sciences Meeting, Reno NV, Jan 2008.

Number of Papers published in non peer-reviewed journals: 1.00

(c) Presentations

A multi-code Python-based infrastructure for overset CFD with adaptive Cartesian grids, A. Wissink, J. Sitaraman, V. Sankaran, D. Mavriplis, T. Pulliam, AIAA paper 2008-0927, presented at the AIAA Aerospace Sciences Meeting, Reno NV, Jan 2008.

Number of Presentations: 1.00

Non Peer-Reviewed Conference Proceeding publications (other than abstracts):

Number of Non Peer-Reviewed Conference Proceeding publications (other than abstracts):   0

Peer-Reviewed Conference Proceeding publications (other than abstracts):

Number of Peer-Reviewed Conference Proceeding publications (other than abstracts):   0

(d) Manuscripts

Number of Manuscripts: 0.00

Number of Inventions:

Graduate Students

NAME	PERCENT_SUPPORTED
FTE Equivalent:	
Total Number:	

Names of Post Doctorates

NAME	PERCENT_SUPPORTED
Zhi Yang	1.00
FTE Equivalent:	**1.00**
Total Number:	**1**

Names of Faculty Supported

NAME	PERCENT_SUPPORTED	National Academy Member
Dimitri Mavriplis	0.33	No
FTE Equivalent:	**0.33**	
Total Number:	**1**	

Names of Under Graduate students supported

NAME	PERCENT_SUPPORTED
FTE Equivalent:	
Total Number:	

Student Metrics
This section only applies to graduating undergraduates supported by this agreement in this reporting period

The number of undergraduates funded by this agreement who graduated during this period: 0.00

The number of undergraduates funded by this agreement who graduated during this period with a degree in science, mathematics, engineering, or technology fields:...... 0.00

The number of undergraduates funded by your agreement who graduated during this period and will continue to pursue a graduate or Ph.D. degree in science, mathematics, engineering, or technology fields:...... 0.00

Number of graduating undergraduates who achieved a 3.5 GPA to 4.0 (4.0 max scale):...... 0.00

Number of graduating undergraduates funded by a DoD funded Center of Excellence grant for Education, Research and Engineering:...... 0.00

The number of undergraduates funded by your agreement who graduated during this period and intend to work for the Department of Defense 0.00

The number of undergraduates funded by your agreement who graduated during this period and will receive scholarships or fellowships for further studies in science, mathematics, engineering or technology fields:...... 0.00

Names of Personnel receiving masters degrees

NAME
Total Number:

Names of personnel receiving PHDs

NAME

Total Number:

Names of other research staff

NAME   PERCENT_SUPPORTED

FTE Equivalent:
Total Number:

Sub Contractors (DD882)

Inventions (DD882)

Forward:

The technical accomplishments described herein cover the first full year of participation of the PI's research group from the University of Wyoming in the HPC Institute for Advanced Rotorcraft Modeling and Simulation (HI-ARMS) project. The role of the University of Wyoming team is to develop, test, and integrate the near body compute engine (NBE) component into the general HI-ARMS simulation software infrastructure. This requires both the development and validation of the NBE capability in stand-alone mode, based on the NSU3D unstructured mesh solver, and the coupling of the NBE solver with the off-body compute engine (OBE) based on the code SAMARC, in addition to coupling with RCAS for structural coupling.

List of Figures:

Statement of Problem:

The principal objective of this project is to develop a near body compute engine (NBE) based on the NSU3D unstructured mesh solver [1] for use as a component in the HI-ARMS software suited named HELIOS. The approach taken in this project, as outlined in the proposal, has been to rapidly advance a research version of the NBE, which is used to demonstrate stand-alone solution capabilities as well as coupling capabilities with the other HI-ARMS software components, while at the same time proceeding with the development of a more thoroughly validated production version of the NBE, which lags the development of the research version, but benefits from the path-finding exercises conducted with the research version in its development.

Accomplishments and Results:

At the initiation of this project, a high priority was placed on rapidly developing a preliminary version of the NBE which included the necessary features to perform stand-alone as well as coupled (within HELIOS) rotorcraft unsteady simulations. With this in mind, the research (non-production) version of the NBE was quickly upgraded to include the arbitrary Lagrangian-Eulerian (ALE) terms required for moving mesh problems, as

well as additional source terms required for the simulation of hover test cases in a stationary setting. A stand-alone hover test case, computed in (non-inertial) steady-state mode, as well as with a moving (rotating) mesh was initially completed for a single-blade rotor discretized with an unstructured mesh. Subsequently, a fully unstructured mesh was generated about a more realistic three-bladed V-22 (TRAM) rotor at 14 degrees collective, and steady (non-inertial) hover simulations were undertaken. Figure 1 illustrates results obtained for this case. The mesh is relatively coarse and contains roughly 1.5 million points. The computed surface pressure coefficients shown in Figure 1a) appear reasonable, and the streamlines produced along a sectional cut are qualitatively similar to those observed with structured grid codes such as OVERFLOW for this case. However, the streamlines at the lower exit plane tend to curve outwards, which is taken as an indication that the simple Riemann-invariant boundary condition used at all outer boundaries is not appropriate at the exit plane. Furthermore, convergence issues and overall accuracy in the predicted force coefficients remained unsatisfactory for these cases. Although investigations into the use of finer meshes, alternate boundary conditions and convergence improvement were undertaken with this version of the NBE, a full investigation of these issues was deferred until the final production version of the NBE was ready for testing.
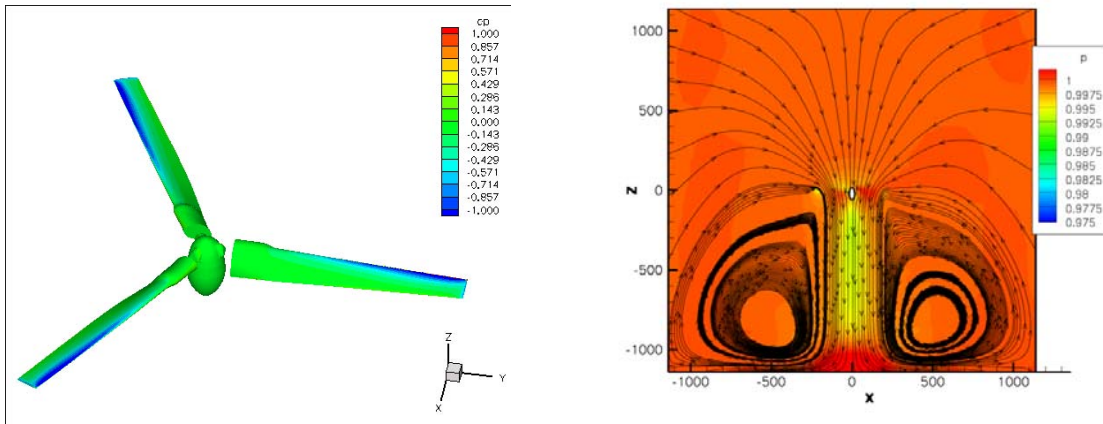

Figure 1: a) Illustration of computed surface pressure coefficients for V-22 TRAM test case at 14 degrees collective using NBE solver in stand-alone non-inertial mode, and b) illustration of computed streamlines at y=0 center plane.

The research version of the NBE was also coupled to the OBE in the HI-ARMS software, using IBLANKing routines and interpolation boundary conditions implemented outside of the NBE software itself, and used to demonstrate a coupled NBE-OBE static grid test

case, involving flow over a sphere at low Reynolds number. One of the successes of this exercise was the demonstration of the convection of vortical structures through the unstructured (NBE) – structured (OBE) grid interface with minimal distortion, as illustrated in Figure 2, for flow over a sphere, taken from reference [2]. While the research version of the NBE has been demonstrated successfully for these cases, the computational efficiency and robustness of this version of the NBE remain suboptimal, and these issues will be addressed with the deployment of the production version of the NBE.
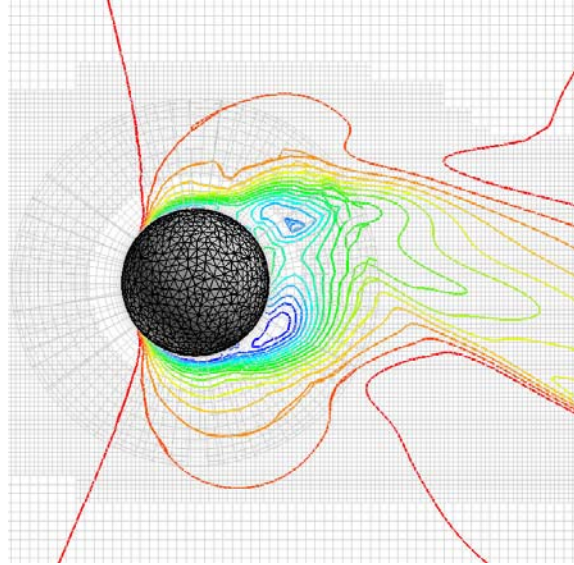

Figure 2: Illustration of coupled Near-Body Compute Engine, NSU3D and Off-Body Compute Engine (SAMARC) simulation of viscous flow over a sphere used for validating both solvers and the intergrid coupling procedures developed under HI-ARMS.

At the outset of the project, the production version of the NBE, namely the NSU3D unstructured mesh solver, was confined to static grid, steady or unsteady simulations. Thus, the initial priority has been to upgrade NSU3D to include all the necessary capabilities required by the HI-ARMS project.

The first upgrade to the NSU3D code consisted of implementing IBLANKing, whereby selected regions of the mesh can be blanked out using a single integer array which covers the entire mesh. This capability has been implemented and tested on simple static mesh test cases.

The second upgrade consisted of incorporating the ability to treat various blocks of unstructured meshes simultaneously and seamlessly within the NSU3D solver. This was implemented by developing a pre-processing facility which merges various pre-existing unstructured meshes into a single data-structure, while keeping flags of the original mesh

or block id to which each mesh point belongs. This information is carried throughout the entire preprocessing operation, and is available to the solver at run time.

The NSU3D code has also been "pythonized", meaning it has been wrapped with a Python scripting language interface in order to enable communication with other HI-ARMS software modules.

Finally, the NSU3D code as also been upgraded to handle dynamic mesh cases, which requires the incorporation of grid speed terms, with careful attention to conservation issues, as governed by the Geometric Conservation Law. This implementation follows the approach demonstrated in the research version of the NBE, and is based on the approach described by the PI in reference [3].

Currently, initiating a run with NSU3D (and thus the NBE) requires a substantial amount of pre-processing operations, which are carried out using a sequence of pre-processing codes for reformatting the grid, extracting the necessary data-structures, constructing the coarse multigrid levels, and partitioning the mesh. The complete sequence of preprocessing operations can become error prone for novice users, and it was decided that some level of automation would be beneficial early on in the program. A scripting procedure has thus been developed for the preprocessing operations, which enables full automation of all tasks involved from the reading of the original grid file, to the running of the NSU3D solver.

Another component of this project involves the development and use of robust mesh deformation techniques. A mesh deformation strategy based on linear elasticity has been under development within the UW group, and this has been tested and packaged for use in the HI-ARMS project. This approach, including an optimized extension of the methodology has been described in reference [4]. The mesh deformation code can currently run as a stand-alone code, and is being packaged to run as a callable routine from within the HI-ARMS software suite.

The most pressing future work will concentrate on validating the production version of the NSU3D solver for performing stand-alone hover simulations, and coupled simulations with the OBE module within the HI-ARMS software, thus replacing the research version of the NBE currently used by the HI-ARMS software.

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